Ceccaldi PF (1962) Examination of firearms and ammunition. In: Lundquist F (ed.) *Methods of Forensic Science*, vol. 1. New York: Interscience.

Davis JE (1958) *An Introduction to Tool Marks, Firearms and the Striagraph*. Springfield: Charles C Thomas.

Ezell EC (1983) *Small Arms of the World: A Basic Manual of Small Arms*, 12th edn. Harrisburg: Stackpole Books.

Ezell EC (1986) *The AK47 Story: Evolution of the Kalashnikov Weapons*. Harrisburg: Stackpole Books.

Ezell EC (1988) *Small Arms Today: Latest Reports on the World's Weapons and Ammunition*, 2nd edn. Harrisburg: Stackpole Books.

Hatcher JS, Jury FJ and Weller J (1957) *Firearms Investigation, Identification and Evidence*. Harrisburg: Stackpole Books.

Hogg IV (1977) *The Encyclopedia of Infantry Weapons of World War II*. New York: Thomas Y. Crowell.

Hogg I (1996) *The Story of the Gun*. New York: St Martin's Press.

Hogg IV (1999) *The Greenhill Military Small Arms Data Book*. Mechanicsburg: Stackpole.

Hogg I and Adam R (1996) *Jane's Guns Recognition Guide*. Glasgow: HarperCollins.

Jinks RG (1991) *Artistry in Arms: the Guns of Smith & Wessson*. Springfield: Smith and Wesson.

Kettrick JF (1983) *Small Arms Identification and Operations Guide – Eurasian Communist Countries (U)*. Washington: Defense Intelligence Agency.

Kettrick JF (1984) *Small Arms Identification and Operations Guide – Free World*. Washington: Defense Intelligence Agency.

Koller L (1953) *Complete Book of Guns*. New York: Maco Magazine Corporation.

Krcma V (1996) Fluted and annular grooved barrel chambers in firearms. *Journal of Forensic Sciences* **41**:407–417.

Mathews JH (1962) *Firearms Identification*, vols 1–3. Springfield: Charles C Thomas.

Nichols RG (1997) Firearm and toolmark identification criteria: a review of the literature. *Journal of Forensic Sciences* **42**:466–474.

Rowe WF (1988) Firearms identification. In: Saferstein R (ed.) *Forensic Science Handbook*, vol II. Englewood Cliffs: Prentice Hall.

Smith WHB (1997) *Pistols and Revolvers*. Birmingham: Palladin Press.

Smith WHB (1997) *Rifles*. Birmingham: Palladin Press.

Footprints *see* **Pattern Evidence**: Bare Footprint Marks.

Footwear *see* **Pattern Evidence**: Footwear Marks.

Forensic Science *see* **Criminalistics**.

FORGERY AND FRAUD

Contents

Counterfeit Currency
Payment Cards

Counterfeit Currency

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Introduction

Since ancient times and across civilizations, many types of items, including stones, shells, spices, chocolate, beads, livestock and various metals, have been used as symbols of value for purposes of trade. It was not until after the seventeenth century that printed paper came into use as the chief instrument for direct transactions. When Marco Polo brought back tales that paper currency served as money in China in the thirteenth century, he was met with disbelief in the West, where trade was based on coins, crops and service. Yet, by this time, paper money in China already dated several centuries to the T'ang dynasty. The use of paper currency survived in China until the end of the fourteenth century (under the Ming dynasties), after which its use was abandoned. In China, the long-standing use of paper money was linked to the heavy-handedness of the centralized government in forcing its acceptance and in refusing alternative sources of personal value.

In contrast, in the West, the first appearances of paper currency were prompted by emergency situations in the form of coin shortages. In Sweden in 1661, a shortage of silver forced the first appearance of paper money but its use was met with distrust and fear that the nation's now overly portable wealth would quickly flee the country in the pockets of foreigners. A few years later, paper money was introduced in North America when a delay in the shipment of soldiers' pay in Canada prompted authorities to monetize and distribute playing cards – the highest quality paper available – overprinted with monetary values, official seals and signatures in lieu of the normal payments in the coin of the realm.

Counterfeiting

As long as money has existed, so has counterfeiting. In fact, although the US Constitution does not specifically authorize the federal government to issue currency, it does specifically authorize punishment for counterfeiting (Article 1, section 8). Penalties for counterfeiting have often been severe, to include execution. Some banknotes have even carried printed warnings such as 'To Counterfeit Is Death'. In fact, counterfeiters are still executed in China today. In the USA, however, the maximum sentence is not so harsh: 15 years imprisonment and $5000 fine.

There were two periods in US history when floods of counterfeit overwhelmed the paper currency supply (during the Continental period and the decades before the Civil War) and threatened its demise. In the middle part of the nineteenth century, so-called 'counterfeit detectors' were commonly used. These were handbooks that described all the genuine notes in circulation, which were issued by state and local banks, and explicated counterfeit flaws in great detail. By the start of the Civil War, an estimated one-third of the currency in circulation was fraudulent.

This counterfeiting problem, along with the need to finance the Civil War, led the US Government in 1863 to authorize a national currency, to be manufactured by the US Treasury Department's newly established Bureau of Engraving and Printing. By 1865, the need for an enforcement agency to fight counterfeiting and protect the integrity of the new currency led to the establishment of the US Secret Service.

The US Secret Service has been extremely effective in carrying out its responsibilities. Over the course of the twentieth century, the US dollar became so stable and trustworthy that it came into popular use throughout the world as not only an instrument of trade, but also of stored value. Thus today, due to the stability of the currency, the economy and the society, the familiar US 'greenback' serves as a *de facto* world currency. In fact, at the end of the 20th century almost $600 billion in paper currency is in circulation worldwide, and an estimated 60% is held abroad, escalating the importance of protecting US currency from counterfeiting.

Genuine Currency

The materials and characteristics of genuine banknotes are produced to certain specifications, but no such standards exist for counterfeit banknotes. Individual counterfeiters set their own standards, and these standards vary widely. Because the counterfeits lack standards, the process of their identification becomes one of proving a negative, i.e. that the specimen is not genuine. Thus, knowledge of the genuine specimen is critical to identifying counterfeits and evaluation is best carried out by direct, side-by-side comparison of the suspect document with a genuine specimen.

Security

Genuine banknotes are designed to be difficult to counterfeit. They are made with special materials applied in ways not easily reproduced, or accessible, to the general public. Banknotes have traditionally been printed by intaglio, offset and typographic printing processes on high-quality rag paper, using highly durable inks in an integrated design with a redundancy of information, especially regarding the value. The design and materials are chosen to be complementary, each reinforcing the other, and to be challenging for counterfeiters to reproduce.

Durability

The specifications for genuine banknotes are determined not only by the need for resistance to counterfeiting, but also for resistance to wear. In its lifetime, a banknote will be handled daily, in multiple transactions, so its construction and materials must be highly durable and resistant to wear. This requirement extends not only to the base substrate and ink, but also to any special design elements, including applied features such as security threads and fibers, reflective or holographic foils, optically active materials and machine-detectable features.

Production Method

Paper/substrate

The traditional substrate for security documents is a highly durable, rough, uncoated rag paper made with cotton, linen or a blend of cotton and linen; other pulps and materials may be added to enhance strength or tear properties, to reduce costs or to increase security. These additional materials may be fillers and binders, other cellulosic fibers to supplement the base materials, or distinctive materials such as natural or synthetic security fibers or planchettes (distinctive tissue or polymer disks added to the paper furnish) to distinguish the security paper from generic rag stock. The security fibers or planchettes may include special materials for overt, covert or forensic identification. The color of the paper may be white, off-white or other pastel shades that complement the design. A typical basic weight of the paper is 80–90 $\mathrm{g\,m^{-2}}$, although some banknote papers weigh in much lower and some higher. By tradition, security papers do not fluoresce under ultraviolet (UV) light stimulation, but the inclusions (security fibers, security threads and planchettes) and the inks may. Security threads, which are nonpaper materials (plastic, metal or actual threads), are inserted during the papermaking process and can be either entirely within the paper sheet or rise occasionally to the surface for a 'windowed' effect. Security threads are often used as convenient vehicles for introducing machine-readable features or more overt characteristics such as legible text or fluorescence properties.

Security papers often include large portrait watermarks registered in the sheet to fall consistently in a localized area within the printed image. In some currencies, the watermark represents an animal or other easily recognizable object that fits with the theme of the note design. These designs are formed directly in the papermaking process, in which areas of greater and lesser fiber density are created to give darker and lighter areas of the paper.

Today, alternate substrates made from polymers or polymer–paper composites are in use or being introduced.

Printing processes

The three printing processes typically used in printing currency are intaglio, typographic (or letterpress) and offset (both wet and dry). Typically at least the main image (often a portrait) is rendered using intaglio, with the vignettes, background details, see-through images and often the reverse sides printed by offset; the serial numbers are added typographically. In some currencies, the images are printed using only offset; US currency is printed using only intaglio and typographic printing.

Intaglio Traditionally, intaglio printing is used mainly for engraved artwork, special announcement cards, invitations and banknotes. In this method, the image to be printed is engraved as lines into a metal plate. Special intaglio ink, which is very viscous and opaque, is forced into the engravings, but wiped from the plate surface. It is then transferred under high pressure to the intended substrate.

The utility of intaglio printing for security documents lies in the characteristic raised, embossed and feathered texture of the image that is not present when other methods are used. Microscopically, the ink can be seen to actually sit on the surface of the paper and spread along individual paper fibers (feathering), giving the image both visual and tactual texture (**Fig. 1**). These textural characteristics are especially important because anecdotal evidence suggests that counterfeits, whether on paper or polymer substrates, are often first questioned because they 'just don't feel right'.

Typographic (letterpress) In the typographic, or letterpress, printing process, ink is applied to a raised surface and transferred by direct impression to the substrate. This method of ink transfer creates an effect known as 'squeeze out', in which the excess ink on the printing surface is forced toward the edges of the image on to the paper, creating a thick ink outline of the image (**Fig. 2**). These characteristics are dependent on the type of plate used, the printing pressure, and the substrate on which the image was printed.

Typical examples of this process are typewriters and date stamps. The utility in banknote printing is that, since the image to be printed can be changed for

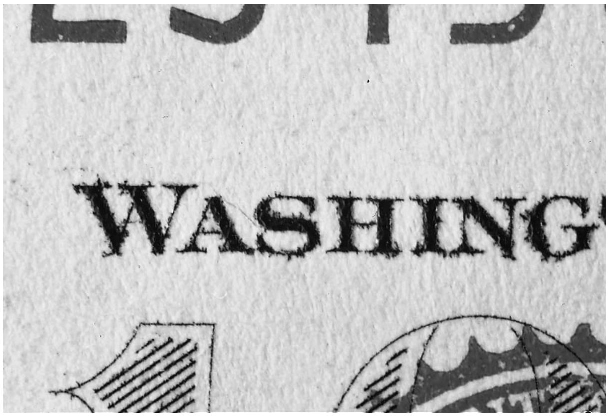

Figure 1 Intaglio printing on genuine US banknote.

each impression, typographic printing can be used to add unique identifiers such as serial numbers or bar codes.

Offset Offset lithographic printing is a planographic process, with neither raised nor engraved features in the printing plates. It is widely used in the commercial arena, especially for printing newspapers and other high-volume products. The image is created in a single surface, with the coplanar image and nonimage areas distinguished chemically so that the image parts will accept ink, but the nonimage areas will not. The ink is transferred from the treated plate on to an intermediate transfer (offset) blanket, then to the target substrate.

Microscopically, the ink appears sharp and even, without build-up of ink near the edges or middle. Since the process is planographic, the printed paper lacks any distortions, such as the indentations or embossing characteristic of letterpress or feathering of intaglio (**Fig. 3**).

Although a commonly used process, offset printing fills a special niche in security document printing. The modern, so-called perfecting presses used by banknote printers are capable of extremely close color-to-color and front-to-back registration. With this equipment, specially designed icons can be printed half on one side of the note and half on the other, forming the complete image only in transmitted light, when both halves can be seen. In addition, these presses are used to apply very fine and interwoven lines in a range of color saturations that challenge the traditional print-shop counterfeiter and modern reprographic equipment as well. With offset printing, the range of microprinted features is extended beyond the capabilities of intaglio.

Another offset process used by banknote printers is dry offset. Not to be confused with waterless offset, where the planographic image and nonimage areas are separated chemically, dry offset uses a raised image plate in combination with an intermediate transfer blanket. The resulting print often exhibits characteristics of letterpress, but lacks any embossment of the paper.

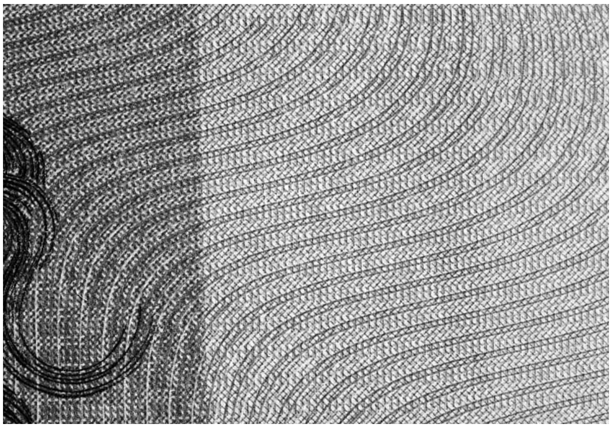

Figure 3 Offset printing.

Screen Screen printing utilizes a stencil to separate the image and nonimage areas. The stencil is fixed to a screen support and allows ink to pass through the image areas to the substrate/paper. The screen pattern is often apparent in the images produced by this method (**Fig. 4**). The ink used for screen printing is thick and the image raised, similar to intaglio, but since no significant pressure is applied to the paper during printing, it lacks any embossing.

Inks

The inks used in security printing are chosen not only for their colour and printing properties, but also for their wear characteristics. Durability is important

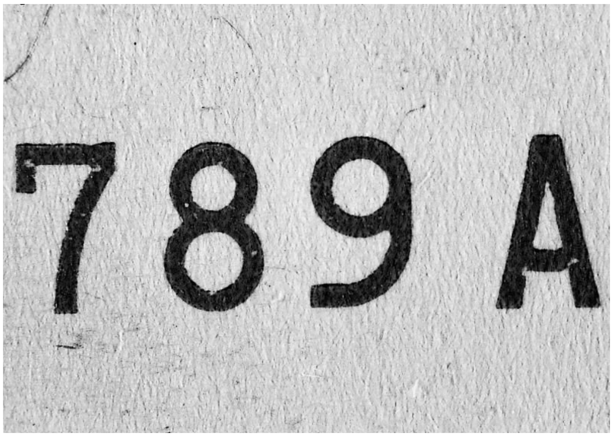

Figure 2 Typographic printing on genuine US banknote.

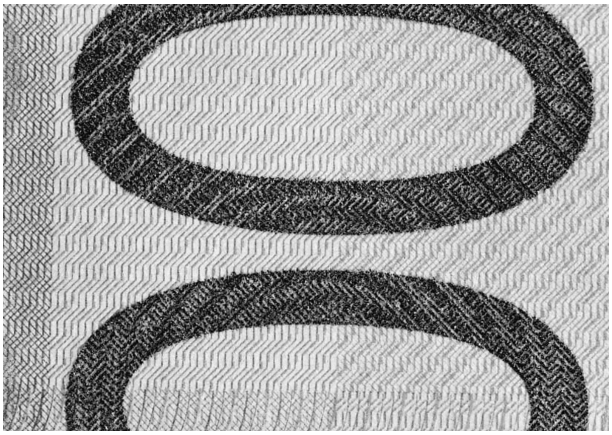

Figure 4 (see color plate 26) Screen printing.

from two aspects. From a utilitarian standpoint, banknotes must withstand the repeated use and occasionally harsh treatment, even laundry and burial, received at the hands of the public. Therefore, to maintain its integrity and utility, a banknote must be sturdy. From a security aspect, the easy removal of the inks from a banknote leaves it vulnerable to counterfeiting abuse, enabling easier color-by-color reproduction or overprinting of higher denominations. For these reasons, inks used in printing banknotes are subjected to a full range of durability tests, including crumpling, laundering and chemical resistance.

Security inks are also flexible and convenient carriers for optical, magnetic or other machine authentication features. Recently, color-shifting inks have come into use. These inks, which use optically variable flakes as pigments, appear to be one color normal to the printed surface, but another color at an oblique angle (**Fig. 5**). Other inks may have special properties such as visible emission under ultraviolet illumination, or certain spectral properties that lead to different appearances under different lighting conditions, or other more covert features for highly secure authentication. The inks used by banknote printers are usually specially designed for the purpose and are not generally available outside the security printing industry.

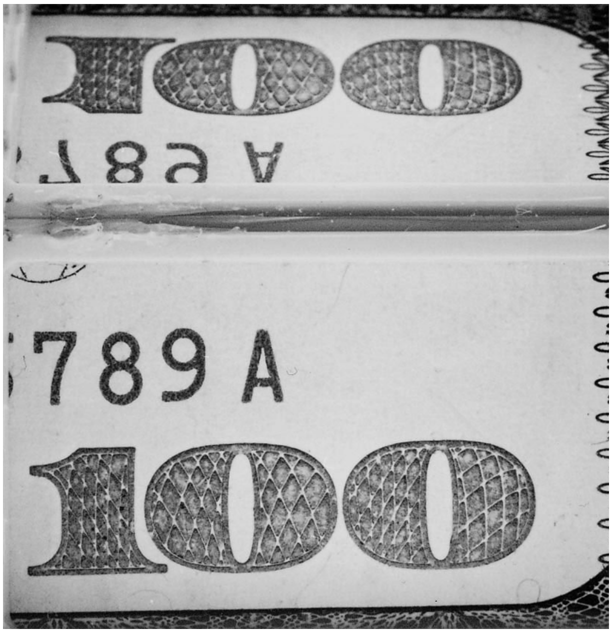

Figure 5 (see color plate 27) Green-to-black color shifting ink on genuine US banknote. Photographed using an angled mirror: green image (below) at normal; black (above) at an oblique angle.

Applied features

In modern banknotes, the security of the design may be further enhanced by inclusion of reflective, holographic or other diffraction-based, image-shifting foils. Such foils may be used as security threads, added during the papermaking process, or added to the surface of the banknote. A number of variations of these foils are available, from three-dimensional holograms to pixel or line-based diffraction gratings. In all cases, the image rendered changes at different viewing angles. Since holographic images are widely available commercially, the clarity and complexity of the images are meant as critical elements to the security of this type of device.

Authentication

As with any production process, errors can and do occur. When these errors reach circulation, they can be misleading to both human and machine authentication. Partly for this reason, secure, modern banknotes are generally designed with a checklist of features and characteristics, beyond the intrinsic design elements, which can be verified to prove or disprove authenticity. The process of authentication then becomes a routine of examining each characteristic until assurance is reached that the sample is a genuine note. If it is not, then it is a counterfeit.

It is crucial to have a basic knowledge of the genuine, including natural variations, to authenticate a document. Natural variations occur in each step of the process, not only in the printing but also in the production of the substrate, resulting in deviations in feathering patterns and in watermark appearance. Familiarity with natural variations can be acquired only by examining a sizeable representative population of notes produced over a period of time. This knowledge provides the basis for differentiating the characteristics of counterfeits from natural variations in genuine notes.

Currency authentication in vending, exchange or banking machines makes use of different machine-readable characteristics of a note. Counterfeit notes produced specifically to defeat these machines may lack image quality. Conversely, counterfeits to be passed to an untrained person may be a good likeness of the genuine note, but lack the less obvious security or machine-readable features. Because of these ambiguities, counterfeit notes range from absurdly obvious to extremely deceptive; therefore, various levels of analyses are required, depending upon the level of simulation/duplication within the suspect note. Crude counterfeit notes will require much less scrutiny than more sophisticated counterfeit notes or notes that are ultimately determined to be genuine.

Examination Techniques for Suspect Currency

Many of the examination techniques used on suspect currency are microscopic, typically requiring 7–40 × magnification for security features, printed images and paper surface evaluations, and 40–100 × power for paper fiber examinations. Various illumination sources are also necessary, including near infrared (700–1000 nm), short- and long-wave ultraviolet and the flexibility to use them in reflected and transmission modes. Various optical filters used in combination with these illumination sources and detectors can be used to differentiate inks. Specialized equipment like microspectrophotometers and micro-Fourier transform infrared (FTIR) spectrometer provide physical and chemical information without the alteration or destruction of the sample. Other methods, such as UV-vis and IR spectroscopy and thin-layer chromatography, are necessary to examine the chemical components of the note.

During the course of examination, the analyst may find that the equipment or expertise needed to perform certain examinations is not available. In this situation, approaching another forensic laboratory, equipped with the necessary resources, may yield vital investigative or forensic information.

Paper/substrate

The foundation of any banknote is the substance on which the image is printed. Whether it is paper, polymer, or a combination of both, its properties and characteristics can have a great influence in the detection of a counterfeit. Because of the obvious role the substrate plays in the banknote, its evaluation is a logical place to start the examination. Most currency paper has features that can be examined physically and are often unique to the banknotes of the issuing country.

Physical examination *Standard light* Many of the properties of the paper/substrate can be observed under standard reflective white light illumination. Such features as the surface finish (topography), color and presence of overt security features can easily be viewed and compared.

Transmitted light Many security features, such as watermarks and embedded threads, are designed to be observable in transmitted light and unobservable in reflected light (**Fig. 6**–**9**).

Alternate light sources

- *UV* Many security features incorporated into the currency paper are designed to react with alternate light sources such as long- and short-wave UV light. Certain security fibers, threads and planchettes fluoresce when excited by UV radiation (**Figs 8**, **10** and **11**). UV illumination is also useful for revealing evidence of simulated features, such as printed watermarks, which may absorb or reflect the light differently from the genuine paper substrate.

Most commercial paper manufacturers increase the whiteness of their paper by the addition of UV-fluorescent optical brighteners. Conversely, genuine banknote paper is made without UV-reactive brighteners and, therefore, exhibits a dull UV response. However, it should be noted that genuine currency paper can become fluorescent by post-issuance contact with substances, such as laundry detergent, which contain optical brighteners.

X-ray Transmitted X-rays are useful for capturing differences in paper thickness, allowing visualization of commercial watermarks such as company logos, text or other images, which, if found on a suspect note, would confirm it as counterfeit. Additionally, X-raying a suspect note can confirm that a security watermark is a printed simulation rather than an actual watermark. Further, the small density difference created by the paper machine's forming wire can be imaged by this technique, allowing for comparison to the genuine.

Microscopic examination Microscopic examination is a powerful tool in the physical analysis of the suspect banknote, allowing the composition and security features of the paper or substrate to be analyzed. The analysis of the fiber content of the paper is conducted by sampling the paper and repulping it. The fibers are then stained and examined microscopically. The fiber species are identified by their morphology, and the paper manufacturing process can be classified by its reaction to various stains.

Security features Under magnification, security features like fibers, threads and planchettes can be examined for their physical characteristics, such as color and morphology. Microscopic examination can reveal whether these security devices were embedded in the substrate or simulated by printing or gluing them to the paper (**Figs 12** and **13**). In cases where the

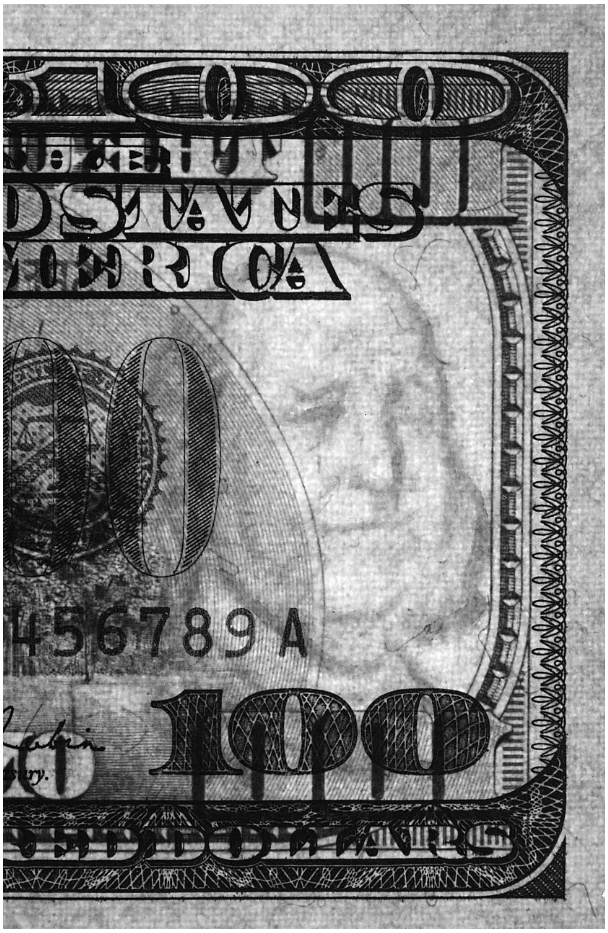

Figure 6 Genuine US $100 Federal Reserve note (FRN) watermark.

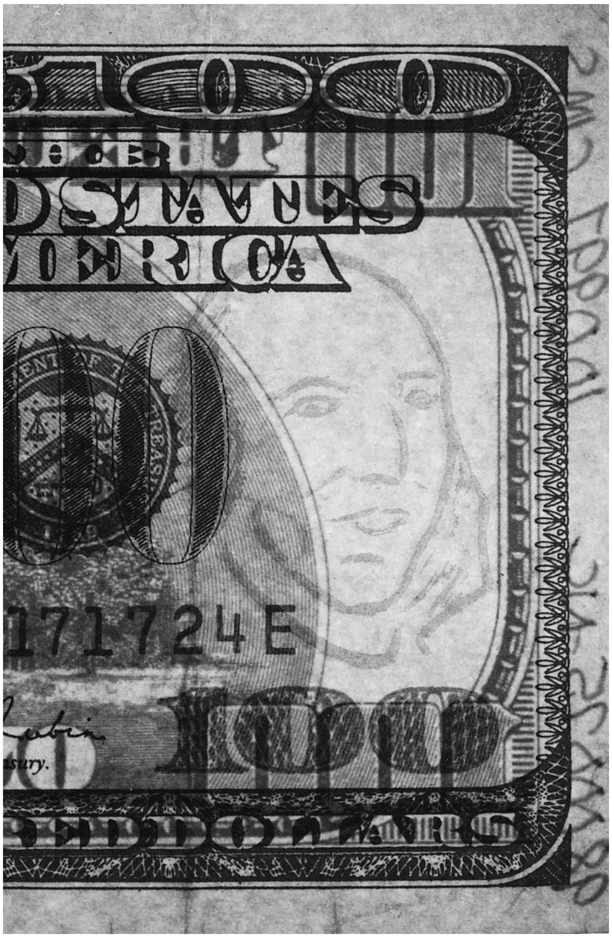

Figure 7 Counterfeit US $100 FRN watermark: simulated by offset printing.

genuine security features are embedded in the substrate, further comparison will often reveal differences between the morphology, color or composition between a genuine and counterfeit feature.

Chemical examination Most currency papers incorporate fillers and sizing not generally used in commercial paper; therefore, chemical analysis of these additives can often differentiate between the counterfeit and genuine papers.

Spectrometric analysis of suspect polymeric banknotes may provide the necessary information to determine the note to be counterfeit.

Bleached genuine Because of the unique characteristics of currency paper, many counterfeiters remove the ink ('bleach') in an attempt to create more deceptive counterfeit notes. The counterfeiter may use low-denomination genuine notes from the target country, bleach the paper, and print the image of a higher denomination. Since the paper is genuine, the paper-based security features will also be genuine and an examination of these features will not alert the examiner to the fact the banknote is counterfeit. Alternatively, the counterfeiter may choose to use a foreign banknote in order to reduce expenditure. An examination of such a note would reveal that the genuine security features of the paper are not consistent with those used in the target country's genuine currency.

Bleached notes may exhibit characteristics of the process. The bleaching process usually involves some chemical and direct physical eradication of the image, resulting in partial removal of the surface sizing and disturbance of the paper fibers. Although extensive wear of a genuine banknote also results in fiber disturbance, this type of wear is characterized by image degradation not present in the counterfeit. Depending upon the effectiveness of the bleaching process, residual images of the original banknote may be apparent.

Quite often the counterfeiter resizes the paper to obtain better printability. The new sizing is usually evident under magnification. The resulting paper often has different surface topography and color when compared to the original genuine paper.

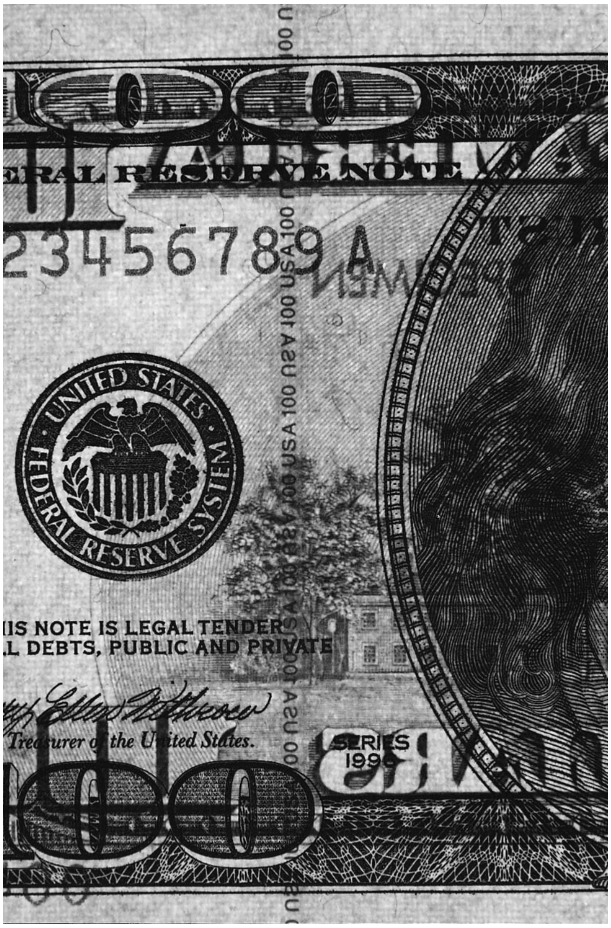

Figure 8 Genuine US $100 FRN security thread.

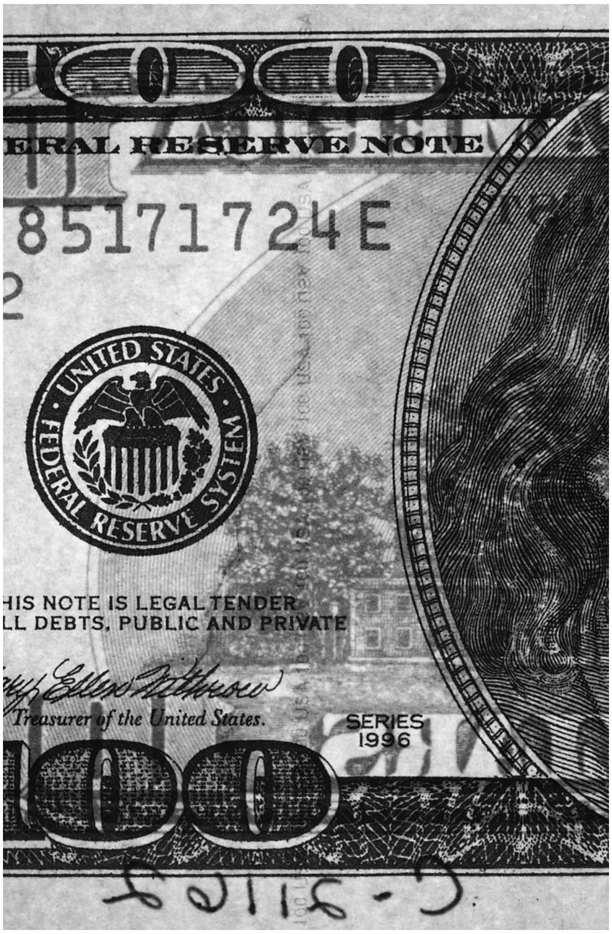

Figure 9 Counterfeit US $100 FRN security thread: simulated by offset printing.

Printed image

In addition to substrate analysis, counterfeits can be identified through analysis of the printed image. The three-dimensional, fine-line detail created by the engraved intaglio plates of the genuine image cannot be easily duplicated except by the very skilled and determined counterfeiter. Because people are skilled at face recognition, the small deviations in the portraits on counterfeits compared to genuine notes are expected to be more noticeable than deviations in other portions of the image. The portrait therefore serves as a logical starting point for image evaluation.

Standard light The first step in the evaluation of image quality is the comparison of the suspect note to a genuine note under good illumination. Differences in the images must be evaluated to determine if they are associated with wear, the natural variation of the genuine, a production anomaly, or because the note is counterfeit.

Some design elements incorporated into the genuine image create distortions (moiré) in counterfeit notes produced on low-resolution scanners and copiers or with half-tone processes. These distortions are obvious under normal viewing conditions.

Other security features, like color-shifting inks or optically variable devices, should be evaluated using techniques appropriate for that feature. This may require altering the angle of observation and noting the change in image or color.

Color differentiation of the inks can be aided by spectral analysis.

Transmitted light Examination with transmitted light is used to identify misalignment of front-to-back registered features, which may be an indication of counterfeit.

Alternate light Components with specific photoactive responses within banknote inks are common. Absence of a response or an incorrect response may be an indication of a counterfeit note.

Microscopic examination *Security features* The low-resolving power of most copiers and printers

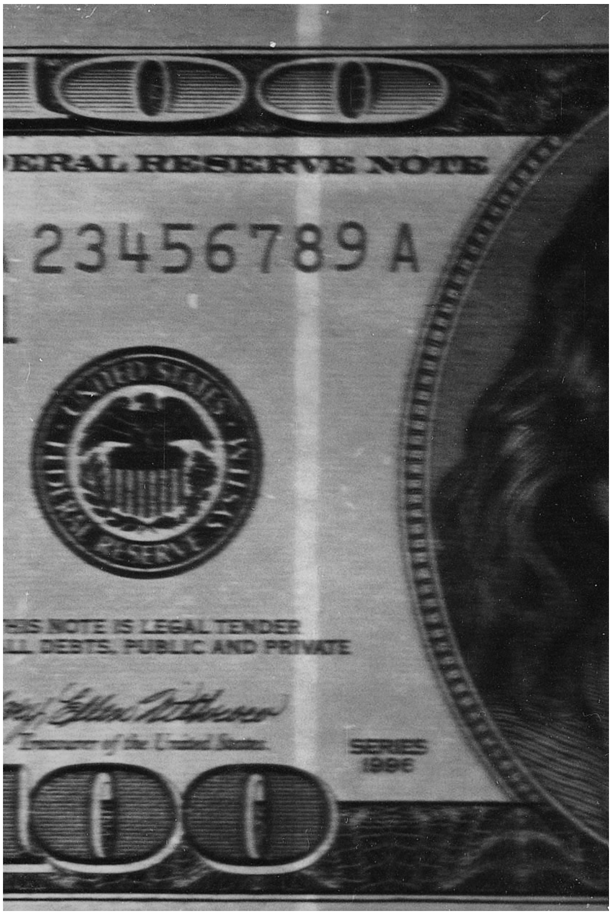

Figure 10 (see color plate 28) Fluorescence of genuine US $100 FRN security thread.

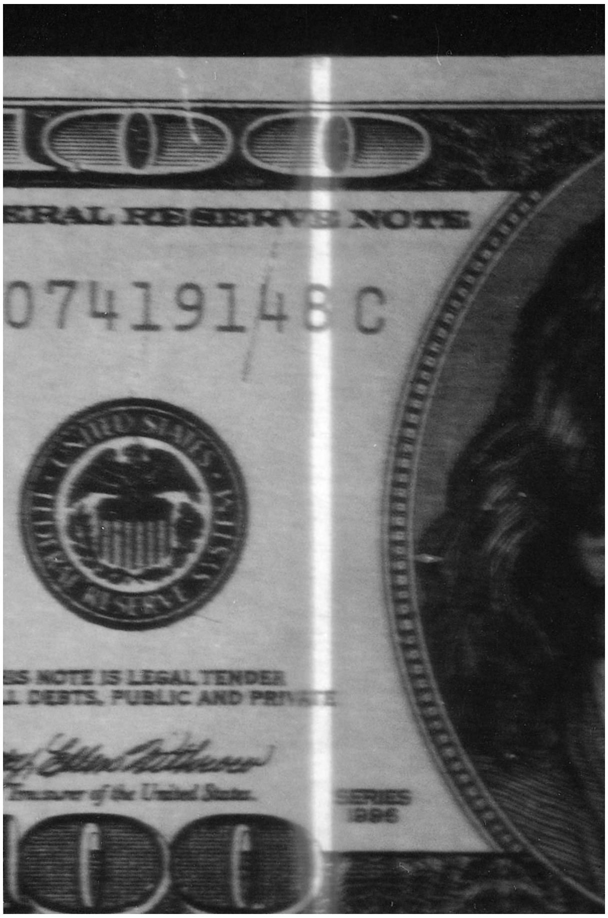

Figure 11 (see color plate 29) Fluorescence of counterfeit $100 FRN simulated security thread.

prevents faithful reproduction of small-scale details in the genuine notes, including microprinted text. If the microprinting is not legible, the note may be counterfeit (**Figs 14** and **15**).

Image deviation from genuine Some counterfeits are produced using methods and materials very similar to genuine (**Figs 16** and **17**). For these types of counterfeits, it may be easier to distinguish the counterfeit from the genuine based on differences in the images rather than on analyses from the materials used. Such cases require meticulous microscopic comparisons.

Printing process determination Images created by

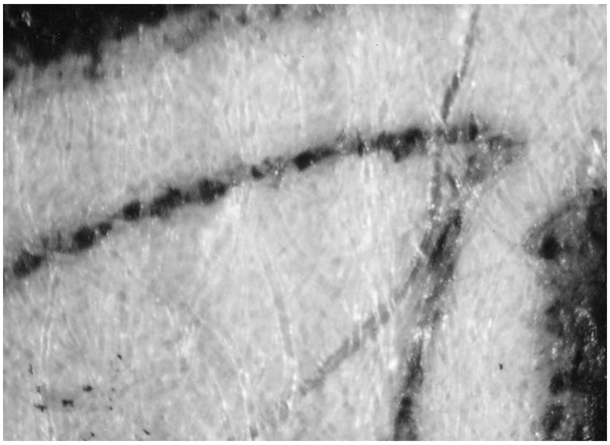

Figure 12 Genuine embedded security fibers.

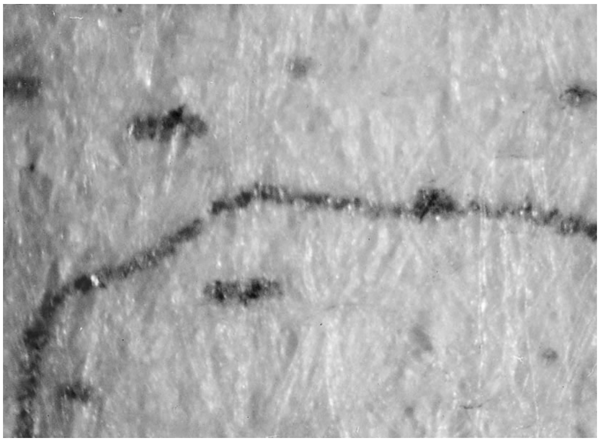

Figure 13 Simulated security fibers: printed offset.

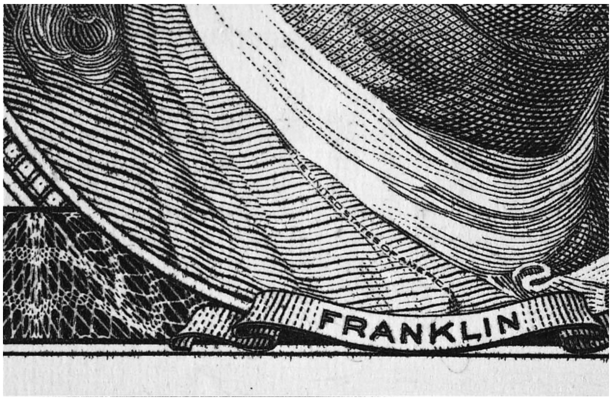

Figure 14 Microprinting on genuine US $100 FRN.

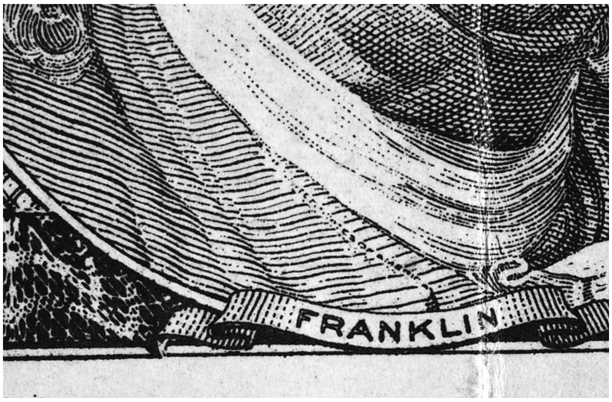

Figure 15 Microprinting on counterfeit US $100 FRN.

the various printing processes have corresponding properties characteristic of the physical or chemical means by which they were produced (**Table 1**). The most reliable tool for the determination of the printing process is microscopic analysis. In addition to intaglio, typographic, offset and screen printing (**Figs 18–21**), the following methods are also used to print counterfeits.

Halftone offset lithography The lithographic process can print only in a single density; it cannot generate gradations of densities to create tonal variations. To print tonal variations, the halftone process is used. This process translates images, with the use of a screen or computer, into a series of dots ranging in size and/or placement, giving the illusion of continuous tone.

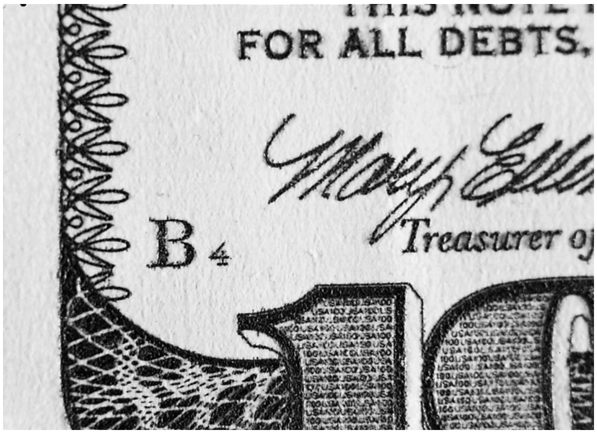

Figure 16 Genuine US $100 FRN.

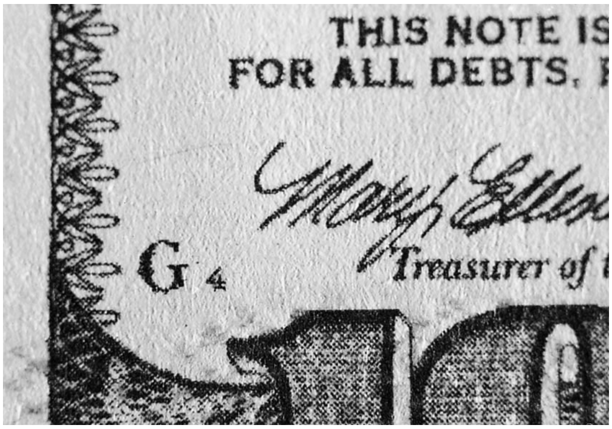

Figure 17 Counterfeit US $100 FRN: printed halftone offset.

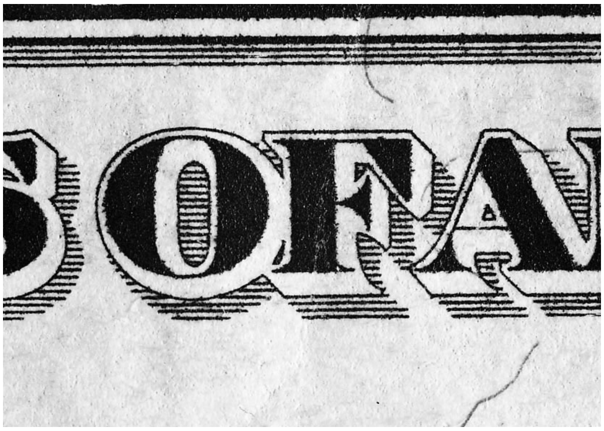

Figure 18 Counterfeit US $100 FRN: printed intaglio.

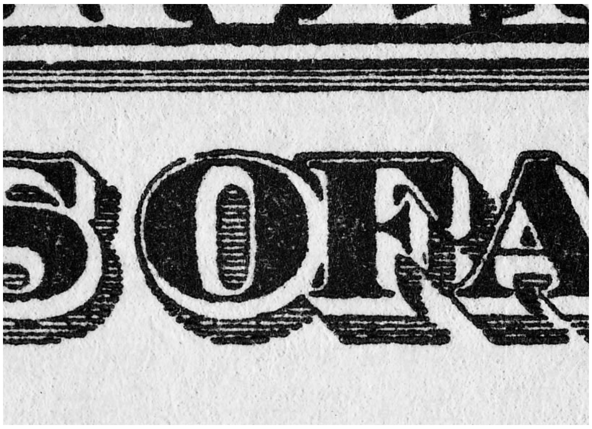

Figure 19 Counterfeit US $100 FRN: printed typographic.

Table 1 Printing process determination by printing process characteristics

Printing process	*Image*	*Characteristics*
Typographic (letterpress)	Imbedded printed image	● Ink is thicker near edges of image, creating an outline of the imaged area ● Paper is embossed with the image
Intaglio	Raised printed image	● Feathering at edges of image ● Paper in the image area is in relief
Screen	Raised printed image	● Fabric pattern
Electrophotographic	Raised printed image	● Dry toner – small plastic particles melted on to the paper surface
Offset lithography	Planographic/flat printed image	● Even ink coverage, sharp edges
Dry offset	Flat printed image	● Ink is generally thicker near edges of image, creating an outline of the imaged area
Inkjet	Planographic/flat printed image	● Undefined image edges ● Ink is absorbed into the paper fibers

Full/process color halftone Process color separation and printing is a method used in the commercial printing industry to translate the various shades and colors captured in color photography into a halftone print consisting of only four colors: cyan, yellow, magenta and black. Although the resulting print consists of only four colors, it creates the illusion of reproducing the wide range of colours contained in the original (**Figs 22** and **23**).

Electrophotographic Electrophotographic processes that use dry toner (e.g. most copying machines

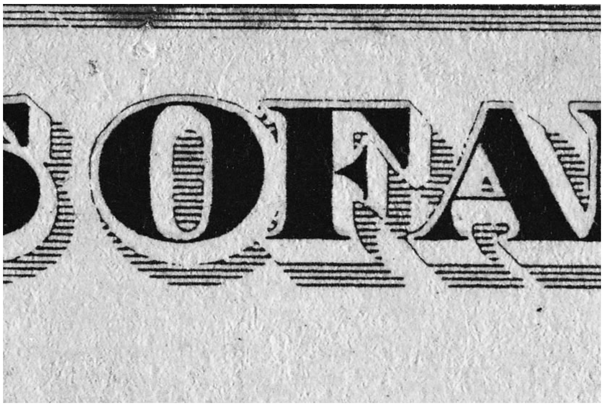

Figure 20 Counterfeit US $100 FRN: printed offset.

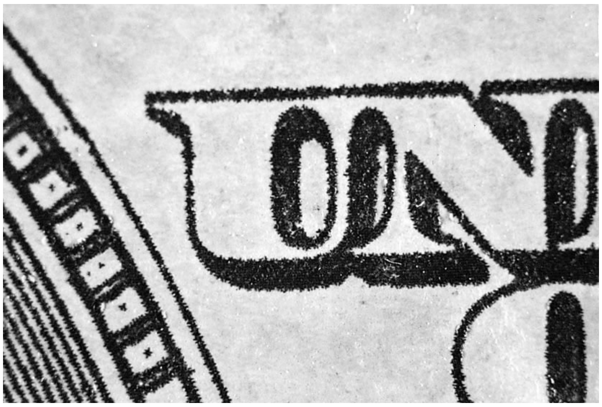

Figure 21 Counterfeit US $100 FRN: printed screen.

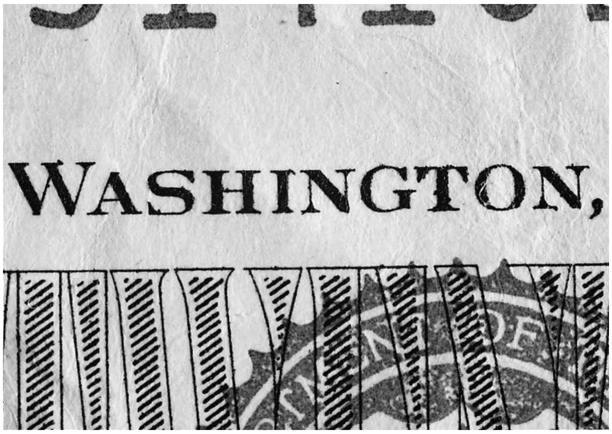

Figure 22 (see color plate 30) Genuine US $20 FRN.

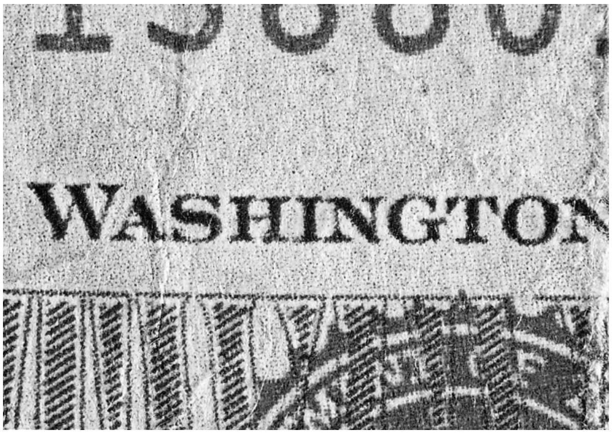

Figure 23 (see color plate 31) Counterfeit US $20 FRN: full color halftone offset.

and laser printers) result in images composed of tiny dots of fused plastic particles. Microscopically, the toner looks like plastic melted on to the surface of the paper (**Fig. 24**).

Inkjet Microscopically, these images are composed of ink spots that have been absorbed into the paper and appear flat. If two or more colours are printed close together, mixing of the inks might be apparent (**Fig. 25**).

Chemical examination Spectrometric, elemental and chromatographic analyses of the pigments, dyes and vehicles provide further avenues for comparison.

Investigative Information from Counterfeit

All aspects of the components and processes can provide valuable investigative information. This information may lead to the discovery of the counterfeiting operation.

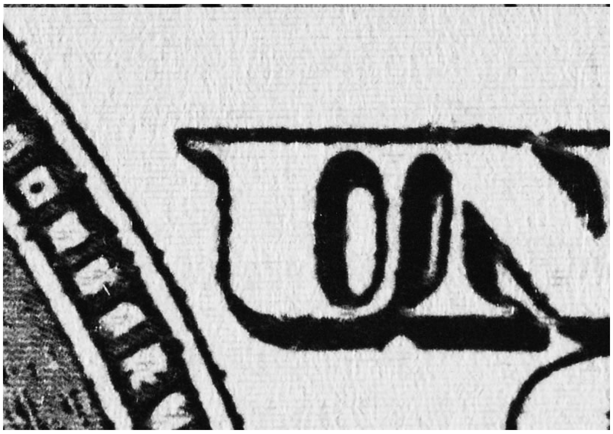

Figure 24 (see color plate 32) Counterfeit US $100 FRN: toner full color copier/printer.

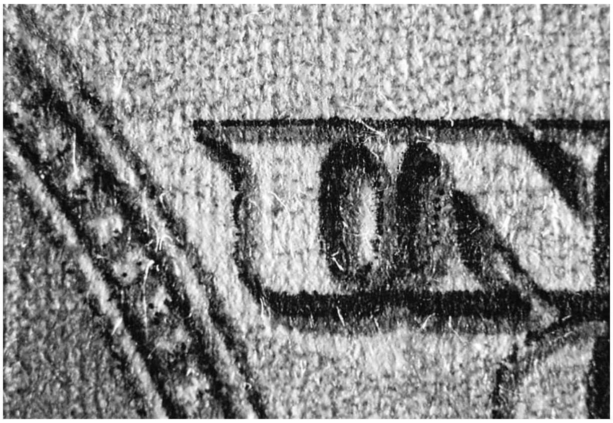

Figure 25 (see color plate 33) Counterfeit US $100 FRN: inkjet full color copier/printer.

Paper

Information such as the identity of the commercial paper based on identification of a watermark or identity of the country of origin by the paper's security features may provide a starting point for an investigation. The paper analysis may also provide valuable evidential corroboration with other counterfeits or with seized paper from a suspected counterfeiting operation.

Image comparison

The examination and analysis of the image not only provides printing process and equipment information, but can also supply the means to associate the counterfeit note with the components of its production. These include the original genuine note used as a pattern for the counterfeiting as well as any photographic negatives, printing plates or digital images used in the process. These components can be associated with the counterfeit based on the uniqueness of each genuine note and the transference of these unique characteristics to the images used to create the counterfeit. Image comparisons may also enable portions of different counterfeit notes, such as the front- or back-plate images, to be linked.

Inks Investigative and corroborative information may be obtained through the use of comparison libraries to identify the manufacturer of an ink used to produce a counterfeit note.

See also: **Analytical Techniques**: Microscopy. **Forgery and Fraud**: Payment Cards, **Document Analysis**: Analytical Methods; Forgery/Counterfeits; Ink Analysis.

Further Reading

Brunelle RL and Reed WR (1991) *Forensic Examination of Ink and Paper*. Springfield, IL: Thomas.

Carpenter CH, Leney L, Core HA, Cote WA Jr. and Day AC (1963) *Papermaking Fibers*. Technical publication 74: New York: State University College of Forestry at Syracuse University.

Church SE (October 1994) Security printing and specialty papers. *International Printing and Graphic Arts Conference*, Technical Section. 18–20 October. Montreal: Canada.

Committee on Next Generation Currency Design, Nationals Materials Advisory Board, Commission on Engineering and Technical Systems, National Research Council (1993) *Counterfeit Deterrent Features for the Next-Generation Currency Design*. Publication NMAB-472. Washington, DC: National Academy Press.

Durst SJ (1978) *History of the Bureau of Engraving and Printing*. Washington, DC: Sandford J Durst.

Eldred NR (1992) *Chemistry for the Graphic Arts*. Pittsburgh: Graphic Arts Technical Foundation.

Hessler G (1983) *The Comprehensive Catalog of U.S. Paper Money*. Port Clinton, OH: BNR Press.
Schafrik RE and Church SE (1995) Protecting the greenback. *Scientific American* vol. 273(1): July 40–46.
Stevenson DL (1994) *Handbook of Printing Processes*. Pittsburgh: Graphic Arts Technical Foundation.
van Renesse RL (ed) (1988) *Optical Document Security*. Boston, MA: Artech House.
Weatherford J (1997) *The History of Money*. New York: Crown.

Payment Cards

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Fraud: the Extent of the Problem

Payment card fraud is big business and hundreds of millions of dollars are lost every year to this criminal activity. The exact dollar amount of the losses depends upon the type of fraudulent activity and the country or region of the world where the fraud occurs. Since card programs – MasterCard, Visa, etc. – use different accounting methods to calculate losses, it is difficult to determine exactly how much the industry loses to fraud.

In economically developed countries, payment card fraud is more of a problem than in the European eastern block and other economically developing countries. In the developed countries, the use of payment cards represents a significant portion of each country's payment system. With the increased usage of cards in these countries, there has also been an increase in payment card fraud.

Payment card fraud will increase in all countries as the card mix available to consumers expands, from credit cards to check cards, cash cards, debit cards, etc. In developing countries payment card fraud and the resulting losses associated with their use will be of increasing importance. If the dollar losses are significant enough, they could affect the economic health and prosperity of the people in the affected countries. The goal of the payment card industry is to see that this does not happen and to reduce the level of fraud in the economically developed countries.

Payment card programs spend millions of dollars each year on card security features, fraud prevention training, investigators, etc. As new card security features are developed and implemented, criminals immediately try to compromise them. A couple of examples will help illustrate this: the use of the hologram or optical variable device (OVD) and the encoded magnetic stripe. Shortly after cards with OVDs were issued to the public, criminals compromised them by using substitute OVD image foils on their counterfeit cards. In most instances the image foils they used had images that did not resemble a genuine image. Many of them were image foils on children's stickers.

The criminal has only one question to answer when making a counterfeit card: will this card be a passable product, such that somebody will accept it and pay out cash or sell expensive goods because they think it is genuine? If the card is accepted at the point of sale, the criminal has succeeded.

In the 1980s organized criminal gangs in Southeast Asia had people who would supply them with holographically produced image foils with images closely resembling genuine image foils. The quality of the foils and the counterfeit cards they were on posed a significant threat to the payment card industry. Visual inspection of the card by the merchant was not sufficient.

The card payment system was in a transition period at this time, in part because of the quality of the Asian card. The magnetic stripe was becoming more important as a means of verifying the card and for payment authorization and reconciliation. Because the industry was becoming more dependent on the encoded magnetic stripe, new security methods and procedures were developed to insure its integrity.

The magnetic stripe is encoded with account information embossed on the card, and security information not embossed on the card. The magnetic stripe is discussed in more detail later in this article. It was not long after the magnetic stripe was introduced that criminals obtained magnetic stripe readers and encoders, and determined how the stripe, the information on it and the associated payment system worked. Electronic card fraud had begun and now magnetic stripe encoding, reencoding and skimming is a significant problem to the industry.

Criminals compromise card security features as soon as the features appear on issued cards. The card programs continue to research and develop new card security features to keep the products' vulnerability to criminal activity as low as possible. It often seems like an endless succession of invent, implement, compromised, invent, implement, compromised ... The industry goal is to attempt to stay ahead of the criminals and to control losses resulting from their activities.